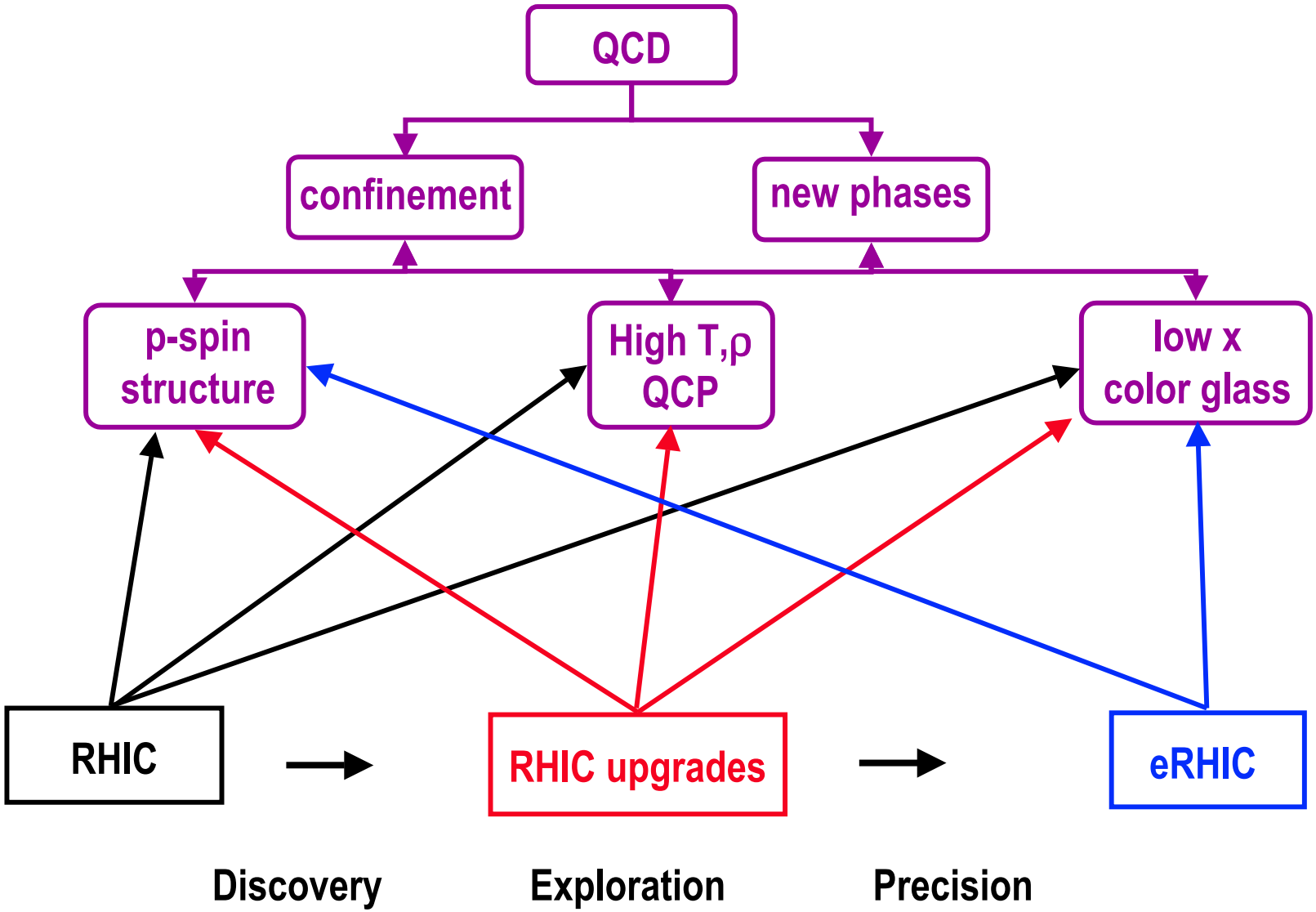
Detector Strategy

Axel Drees, Stony Brook University

NSAC subcommittee meeting, Bethesda, April 4, 2005

- **What I will talk about:**
  - **The Goals of Upgrades: Provide key information not accessible with current RHIC facility and its detectors**
  - **Challenges: Require enhanced detector capabilities and accelerator performance**
  - **Detector upgrades: Cost effective upgrades of PHENIX, STAR to meet challenges**
    Exploit the strengths of existing detector systems
    Developed over past 5 year, 57 institutions involved world wide
    Designed to address broad range of questions in spin and HI physics
  - **Focus on near term upgrades**

RHIC: A Unique QCD Laboratory



RHIC Physics Beyond the Reach of Current Facility

Provide key measurements so far inaccessible at RHIC in three broad areas:

- **High T QCD (AA, pA, and pp):**
  - Electro magnetic radiation (e^+e^- pair continuum)
  - Heavy flavor (c- and b-production)
  - Jet tomography (jet-jet and γ-jet)
  - Quarkonium (J/ψ, ψ' , χ_c and $\Upsilon(1s),\Upsilon(2s),\Upsilon(3s)$)

  requires highest AA luminosity

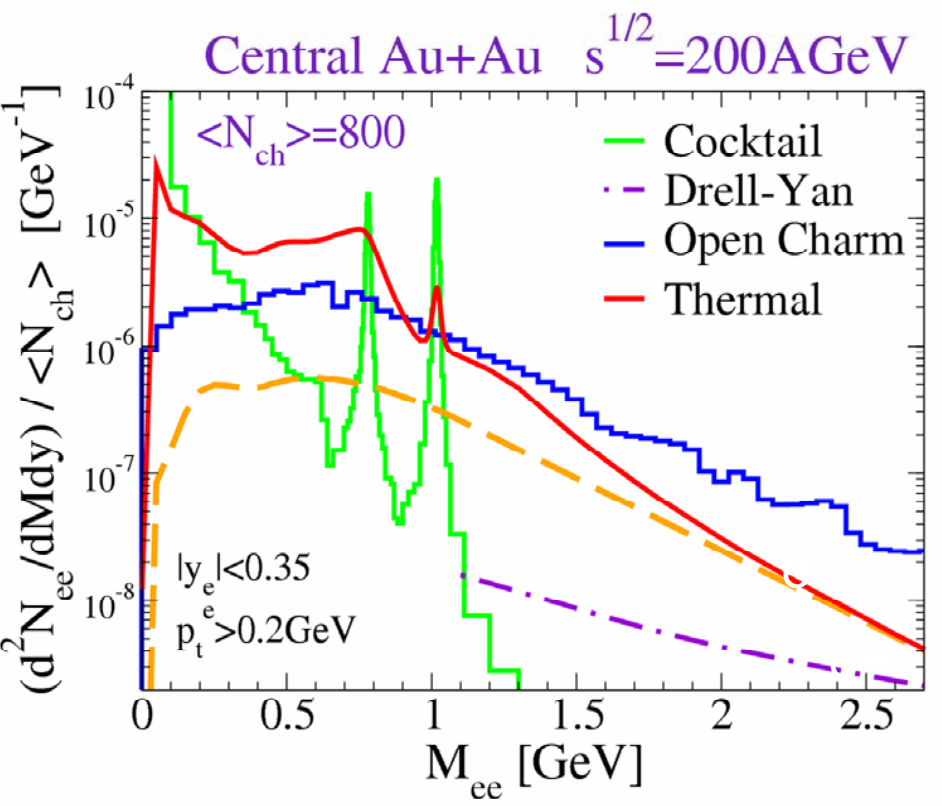
- **Spin structure of the nucleon:**
  - Quark spin structure $\Delta q/q$ (W-production)
  - Gluon spin structure $\Delta G/G$ (heavy flavor and γ-jet correlations)

- **Low x phenomena**
  - gluon saturation in nuclei (particle production at forward rapidity)

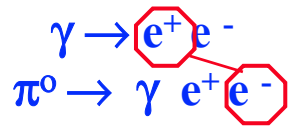
All measurements require upgrades of detectors and/or RHIC luminosity

High T QCD: Low-Mass e^+e^- Pairs at RHIC

R. Rapp nucl-th/0204003



- **Goal:**
  - use sensitivity of e+e- production to
    - Thermal radiation
    - Chiral transition (creation of mass)
    - Quasi particles in sQGP
- **Challenges:**
  - Large charm contribution
  - Huge combinatorial background



- **Detector upgrades:**
  - HBD for PHENIX

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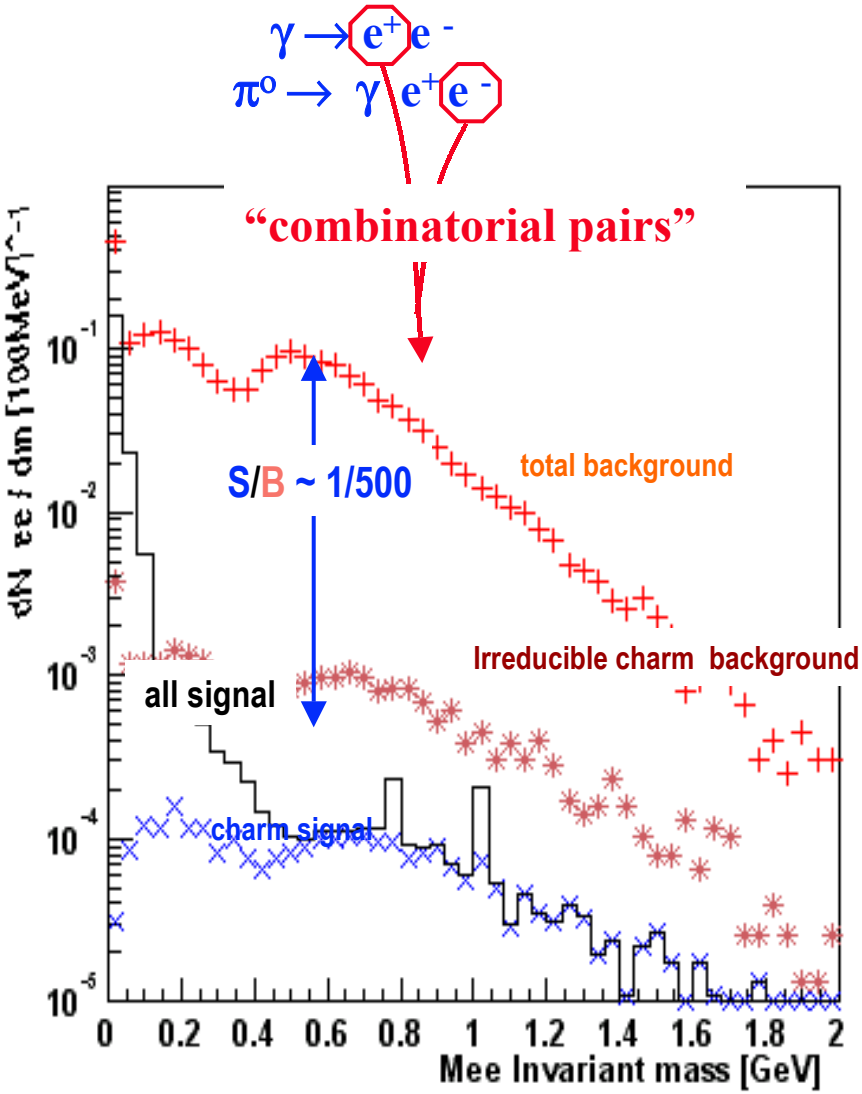
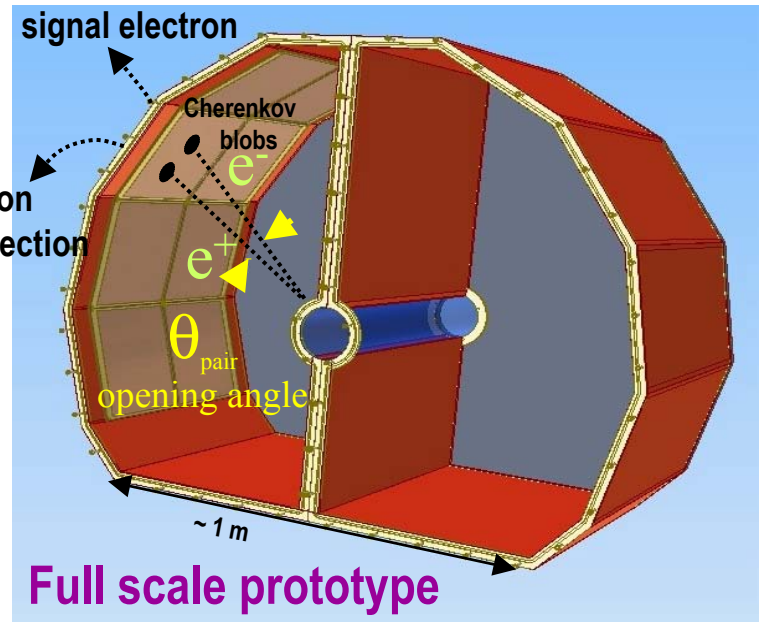
A Hadron Blind Detector (HBD) for PHENIX





- **Full scale prototype under construction**
  - **Weizmann Inst.,** Stony Brook Univ., BNL, Columbia Univ., Florida Inst. Tech., **CNS-Tokyo,** Univ. Mass**, RIKEN BNL Res. Center (RBRC)**

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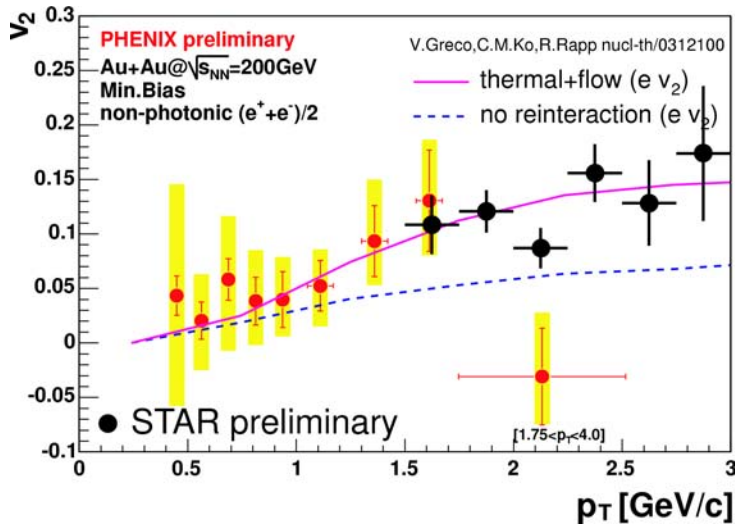
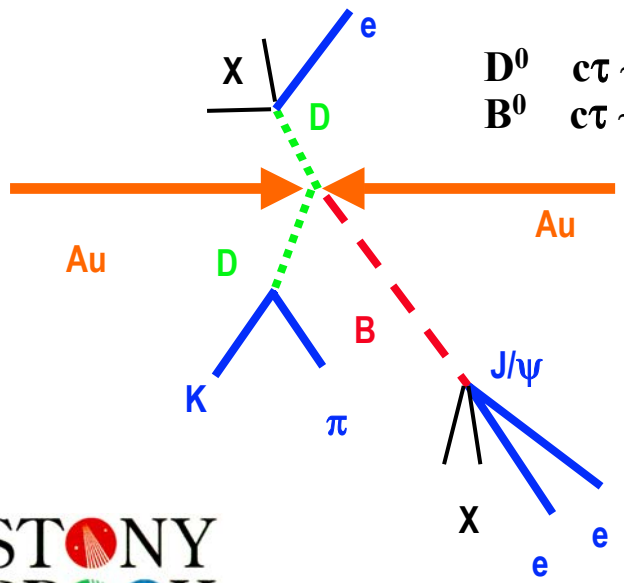
High T QCD: Heavy Flavor Production

Inclusive electrons: D,B → e + X





D^0 $c\tau \sim 125\ \mu m$

B^0 $c\tau \sim 470\ \mu m$

- **Goal:**
  - Test of hydrodynamic properties of sQGP
    - Charm is heavy and is produced by hard scattering early in collision
    - First indications that charm interacts strongly with medium
- **Challenges:**
  - Directly observe charm & beauty
  - Low rate for beauty and high p_T charm
- **Upgrades:**
  - Silicon vertex trackers ($\sigma < 100\ \mu m$)
  - Luminosity upgrade of RHIC

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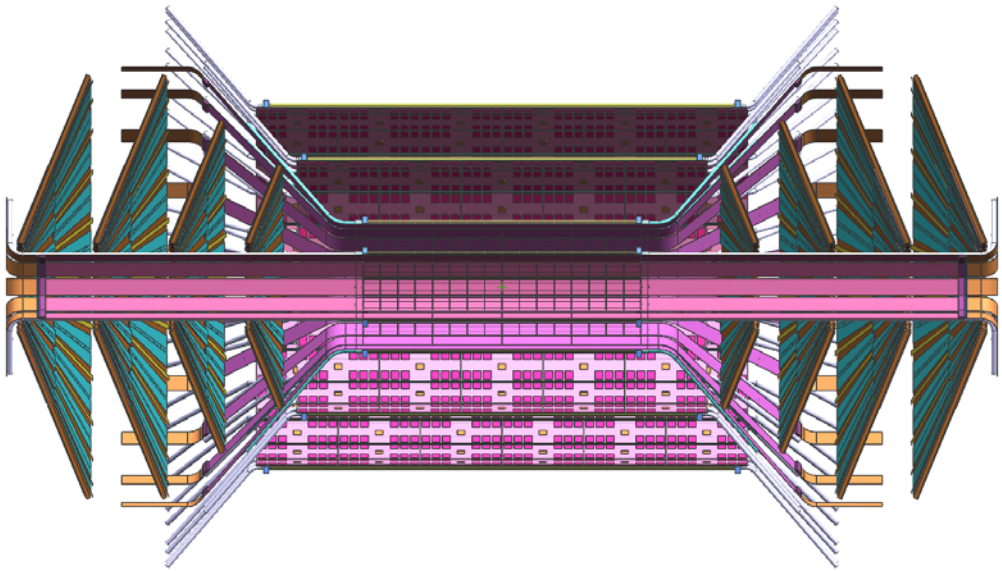
Silicon Vertex Tracker

- **PHENIX: VTX collaboration**
  - **72 collaborators from 14 institutions**
  - BNL, Florida State Univ., Iowa State Univ., **KEK, Kyoto Univ.,** LANL, **Niigata Univ.,** ORNL, **RIKEN, RIKEN BNL Reas. Center,** Stony Brook Univ., Univ. New Mexico, **Ecole Poly Tech, Saclay**
- **Proposal submitted to DOE**
- **Potential funding FY07/FY08**



- **STAR: HFT collaboration**
  - BNL, UC Irvine, UCLA**, Nuclear Physics Inst. Prague, Inst. Recheres Subatomique Strasbourg,** MIT, LBL, Ohio State Univ.
- **Proposal in preparation**

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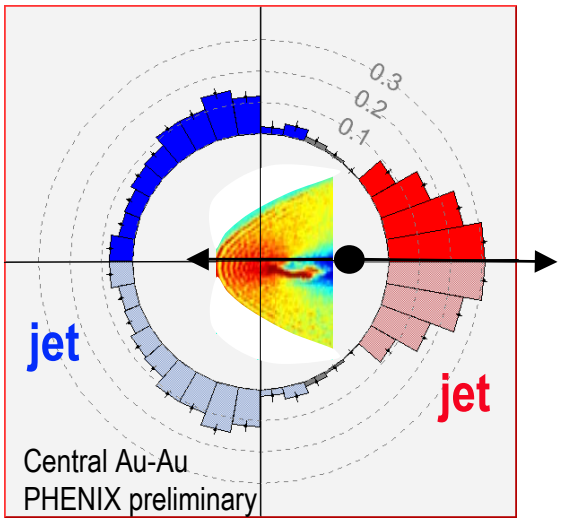
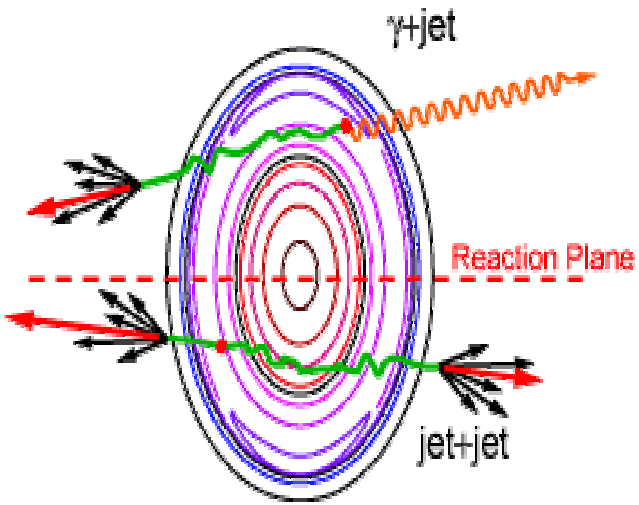
High T QCD: Jet tomography of QGP

Au-Au jet correlations





- **Goal:**
  - determine plasma properties
    speed of sound, opacity, viscosity, equation of state, …
  - Tools: collective behavior, transmission of hard probes, modification of jet fragmentation
- **Challenges:**
  - Obtain detailed angular correlations
    Over Large acceptance in y and p_T
    With particle identification to ≥ 4 GeV/c
  - Low rate for γ-jet
- **Upgrades:**
  - STAR: PID up to 4 GeV (TOF)
    increased rate capability
  - PHENIX: PID up to 10 GeV
    increased tracking and calorimeter acceptance
  - RHIC: luminosity upgrade

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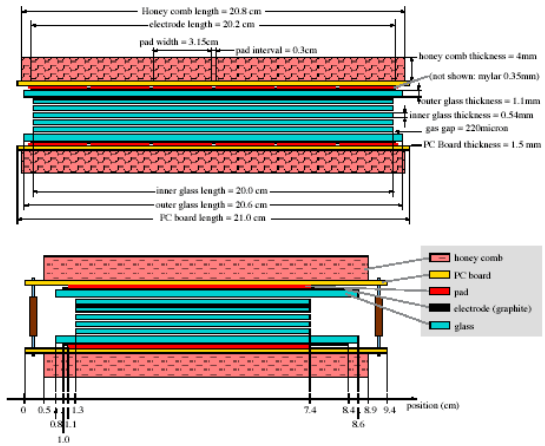
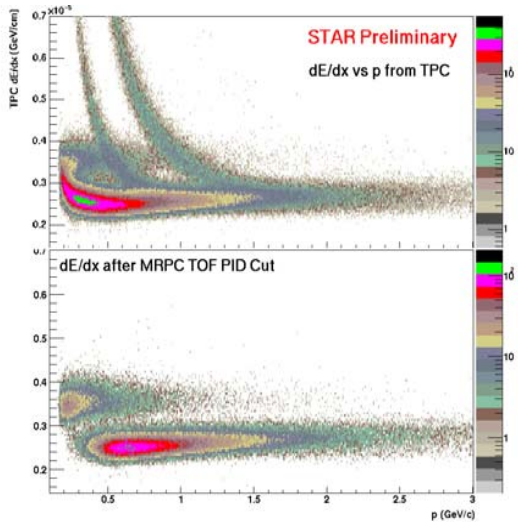
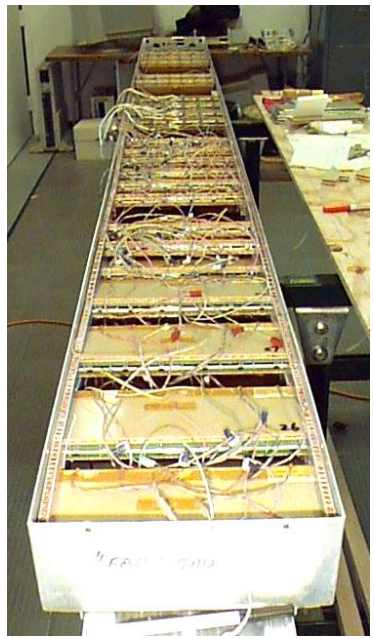
STAR: Time of Flight Upgrade

- **STAR: TOF collaboration**
  - **69 collaborators from 16 institutions**
  - BNL, **Inst. High Energy Physics Beijing**, **Inst. Modern Physics LanZhou**, LBL, **Moscow Engineering Physics Inst.**, NASA, **UNAM & CINVESTA Mexico**, Rice Univ., **Shanghai Inst. Nuclear Research**, **Tsinghua Univ., Inst. Technology of China**, Univ. Texas, UCLA, Univ. Washington, Yale Univ.
- **Construction FY06/FY07**

MRPC design







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High T QCD: Quarkonium Spectroscopy

- **Goal:**
  - Address (de)confinement: J/ψ, ψ' , χ_c and (ϒ(1s),ϒ(2s),ϒ(3s))

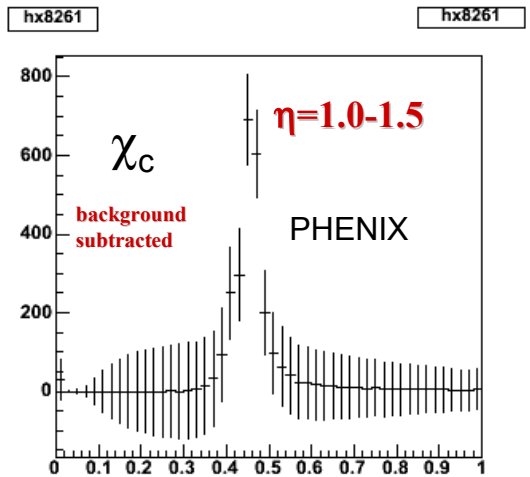
- **Challenges:**
  - Low rates require highest possible luminosity

Example of expected quarkonium statistics from future Au-Au runs (PHENIX)

	RHIC (1.5 nb^{-1})	RHIC upgrade (30 nb^{-1})
J/ψ (ψ')→ μμ	38,000 (1400)	760,000 (28,000)
ϒ → μμ	35	700

  - Open charm reference
  - Measure gamma in coincidence

- **Upgrades:**
  - RHIC luminosity upgrade (electron cooling)
  - PHENIX: forward calorimeter for $\chi_c \rightarrow \gamma J/\psi$
  - STAR: rate capability (DAQ)
    + additional electron identification (TOF)



Central 0-10% Au-Au $m_{\gamma\mu\mu}$-$m_{\mu\mu}$

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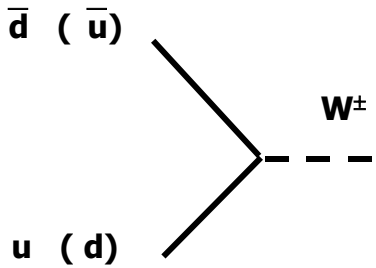
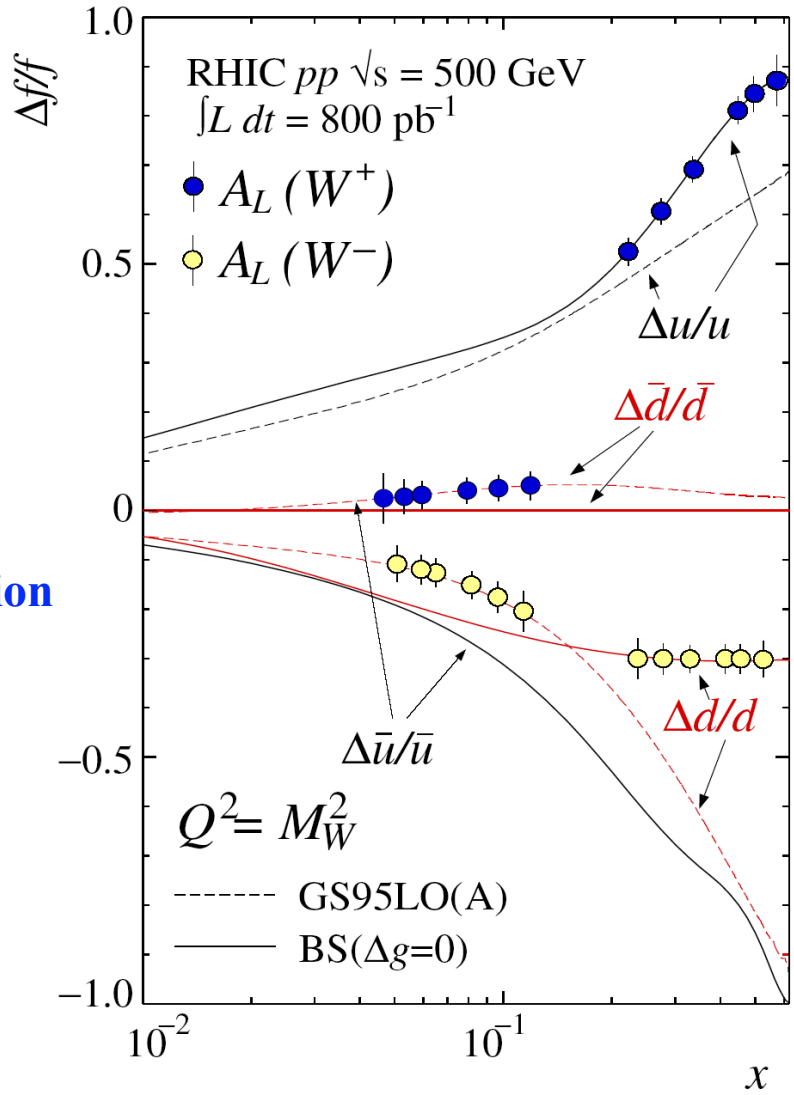
Spin Structure of the Proton: W physics

- **Goal:**
  - q and $\bar{q}$ spin structure of the nucleon
  - Use p↑p → W+X



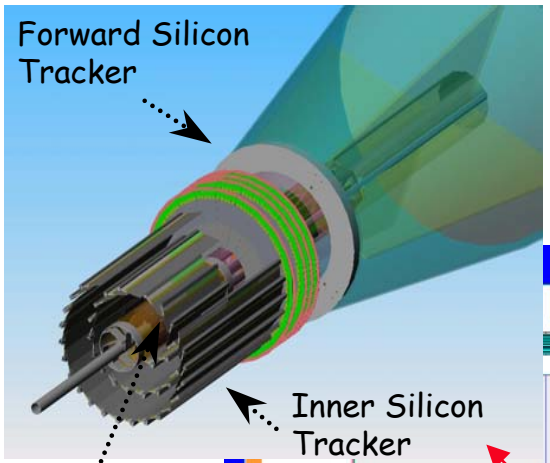
- **Challenges:**
  - nb cross section requires running p↑p at 500 GeV with high luminosity and polarization
  - Reduce MHz event rate to few kHz to tape
  - Unambiguous identification of W^+ and W^-

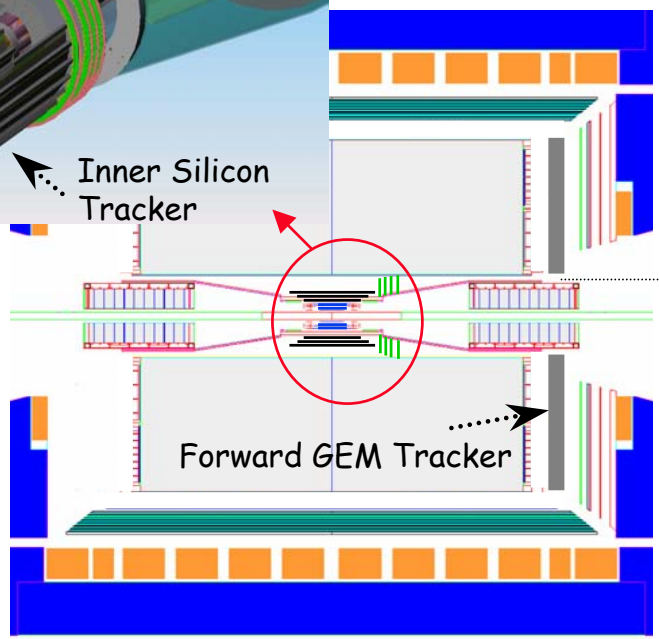
- **Detector upgrades:**
  - PHENIX: high p_T single muon trigger
  - STAR: tracking upgrade

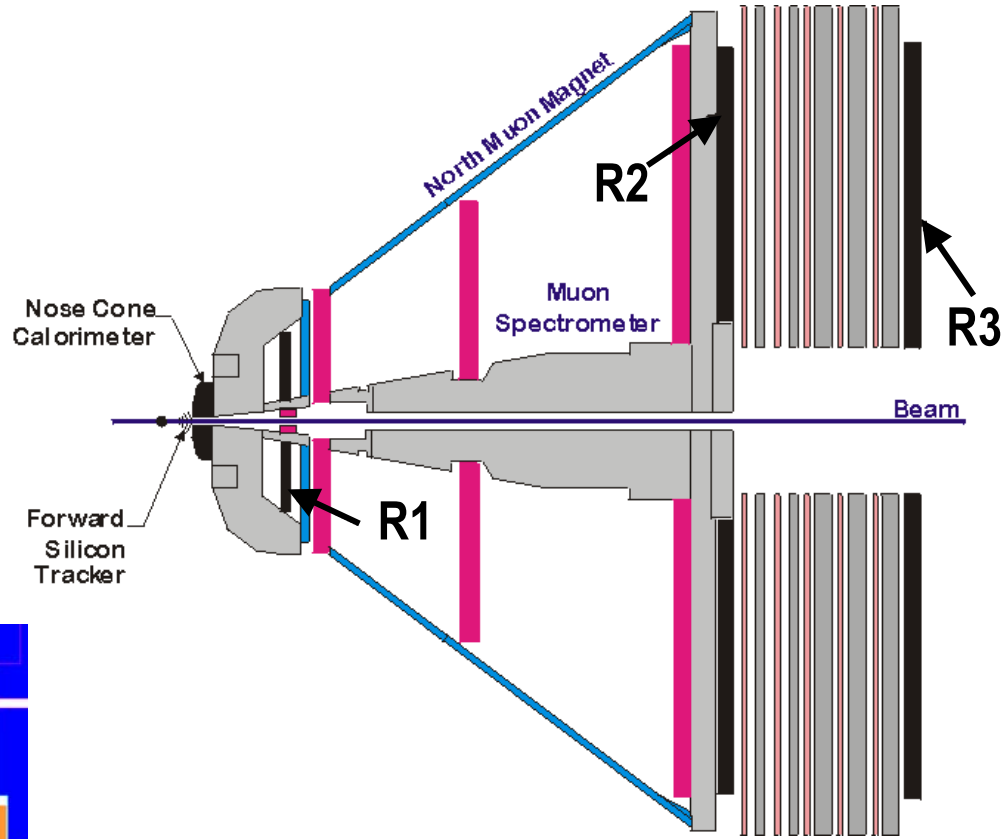


W-Physics upgrades

- **STAR: Tracking Upgrade**
  - **R&D ongoing**
  - ANL, BNL, Indiana Univ., LBL, MIT, Yale Univ., **Zagreb Univ**.







- **PHENIX: muon trigger**
  - **Proposed to NSF**
  - Univ. Illinois-UC, UC-Riverside, Iowa State Univ., Abilene Christian Univ., Univ. Colorado, **Peking Univ.**, Columbia Univ., **Kyoto Univ, RBRC,** Georgia State Univ.

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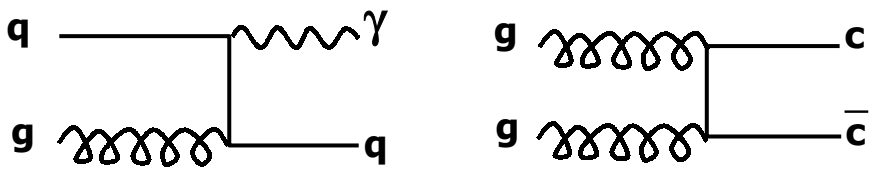
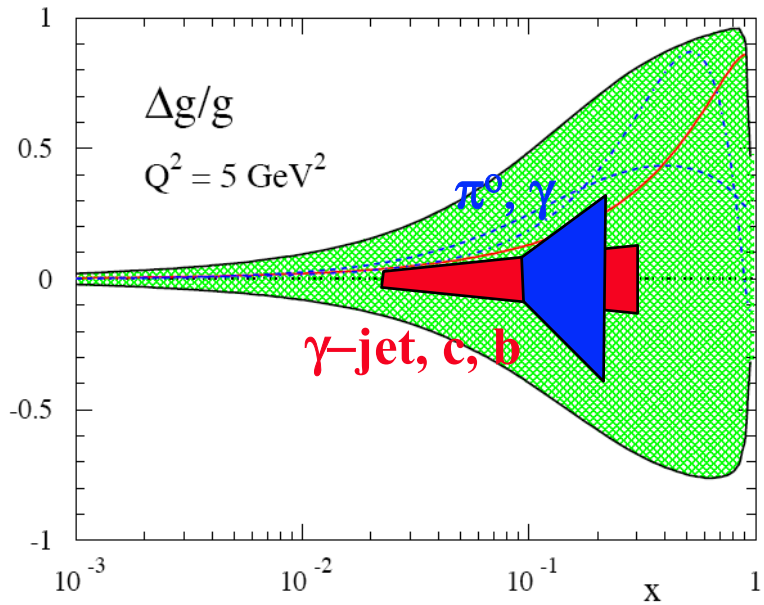
Spin structure of the Proton: Gluon Polarization

- **Goal:**
  - Extend kinematic region
  - Provide new channels for measurement
    - Heavy flavor (c,b) production
    - Exclusive measurements of γ-jet





- **Challenges:**
  - Measure new channels: open charm, beauty and γ-jet
  - Same channels serve as penetrating probes to study sQGP

- **Detector upgrades:**
  - Utilize full suite of PHENIX/STAR upgrades
    - PHENIX: silicon tracker, forward calorimeter
    - STAR: tracking upgrade, forward meson spectrometer

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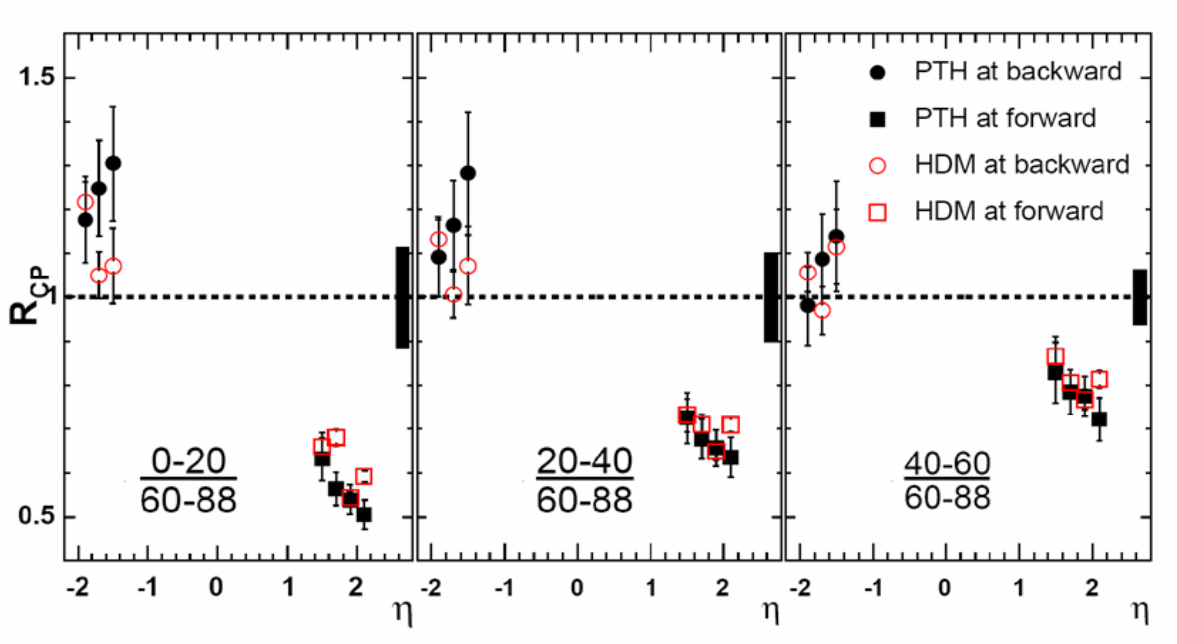
Low x Physics: Forward Upgrades

- **Goal:**
  - Verify/falsify color glass hypothesis; gluon density $xg(x)$ in Au $0.001<x<0.1$



- **Challenge:**
  - Hadron detection at forward rapidity, ie low x
- **Detector upgrades:**
  - STAR: forward meson calorimeter
  - PHENIX: forward EM calorimeter and silicon tracker

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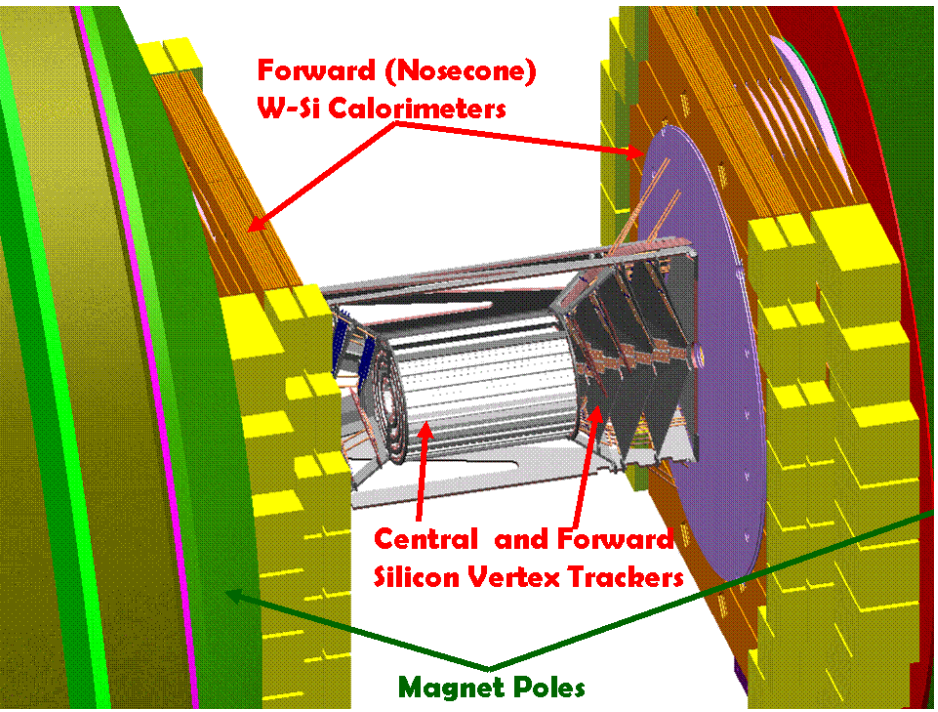
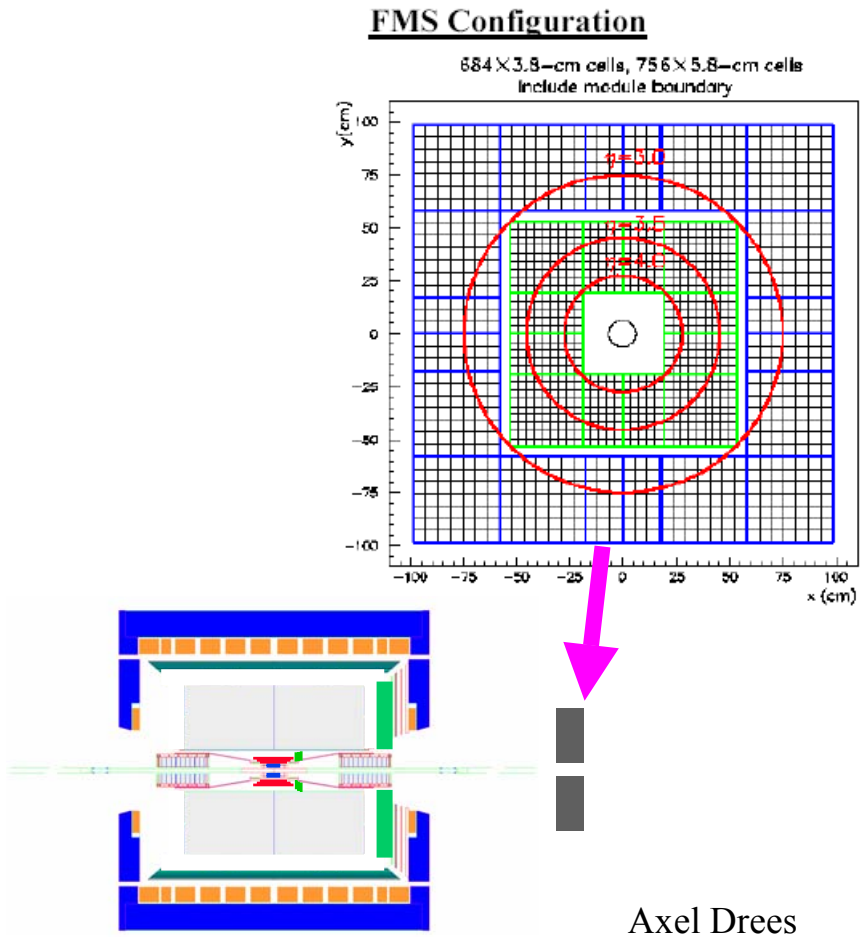
Forward Physics Upgrades: 1<η<3

- **PHENIX: forward calorimeter**
  - **R&D ongoing**
  - BNL, UC-Riverside, **JINR-Dubna, Moscow State U,** Charles Univ., **Czech Tech Univ., Czech Inst of Physics**



- **STAR: forward meson calorimeter**
  - **Proposal submitted to NSF**
  - Penn State Univ., BNL, UC Berkley, **IHEP Protvino,** Texas A&M Univ.



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RHIC Upgrades Overview

Upgrades	High T QCD				Spin		Low x
PHENIX	e+e-	heavy flavor	jet tomography	quarkonia	W	ΔG/G	
hadron blind detector (HBD)	X						
Vertex tracker (VTX and FVTX)	X	X	O	O		X	O
μ trigger				O	X		
forward calorimeter (NCC)			O	O	O		X
STAR							
time of flight (TOF)		O	X	O			
Heavy flavor tracker (HFT)		X		X			
tracking upgrade		O			X	O	
Forward calorimeter (FMS)						O	X
DAQ		O	X	X	O	O	O
RHIC luminosity	O	O	X	X	O	O	O

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X upgrade critical for success
O upgrade significantly enhancements program

Which measurements are unique at RHIC?

- **RHIC spin physics and eRHIC measurements are unique.**
- **High T QCD: General comparison to LHC**
  - **LHC and RHIC (and GSI) are complementary**
  - **They address different regimes (CGC vs sQGP vs hadronic matter)**
  - **Experimental issues: "Signals" at RHIC overwhelmed by "backgrounds" at LHC**

- **High T QCD: Measurement specific (compared to LHC)**
  - **Charm measurements: favorable at RHIC**
    Charm is a "light quark" at LHC, no longer a penetrating probe
    Abundant thermal production of charm
    Large contribution from jet fragmentation and bottom decay
    Bottom may assume role of charm at LHC
  - **Quarkonium spectroscopy: J/ψ, ψ' , χ_c easier to interpreter at RHIC**
    Large background from bottom decays and thermal production at LHC
    Upsilon spectroscopy can only be done at LHC
  - **Low mass dileptons: challenging at LHC**
    Huge irreducible background from charm production at LHC
  - **Jet tomography: measurements and capabilities complementary**
    RHIC: large calorimeter and tracking coverage with PID in few GeV range
    Extended p_T range at LHC

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Summary

- **Goals of RHIC Detector upgrades program:**
  - Key measurements beyond scope of RHIC and its detectors
  - In three areas: high T QCD, proton spin structure, low x phenomena
  - Evolution of the RHIC program: discovery → exploration → precision
- **Challenges for key measurements**
  - Detector upgrades and luminosity upgrade requirements for specific measurements
- **Upgrades program of PHENIX and STAR**
  - Ongoing effort carried by 57 institutions
  - 30 new groups joined PHENIX/STAR over past 4 years, 11 from Europe, many involved with upgrades
  - Staged implementation of upgrades over several years